G4BL SIMULATION OF BEAMLINE APERTURES v2 (03/23/2016)

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1. OVERVIEW

Extracted from G2-docB-681-v50 we list in Table 1 the magnets required for the M2M3 lines. The quad placement along the lines is described by G2-docB-3277 and shown in Fig. 1.

Table 1: Dipoles and quads in M2M3 lines

Type of magnet	Number in M2 and M3 line
SQA	9
SQB	6
SQC	35
SQD	6
SQE	5
4Q16	1
4Q24	2
LQE	1
CDA	1
MDC	4
CMAG	1
SDB	2
SDD	1

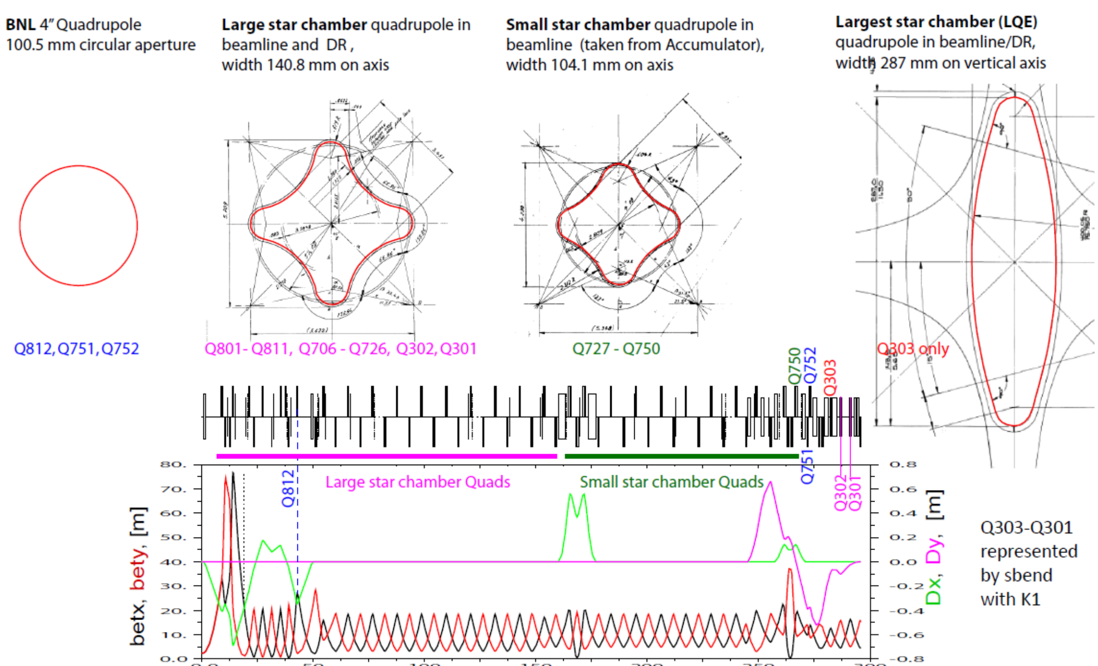


Figure 1: Korostelev's representation of magnet locations.

2. QUADROPOLES

2.1. Drawings

In G2-docB-150 we can find drawings for all quads involved in the beamlines.

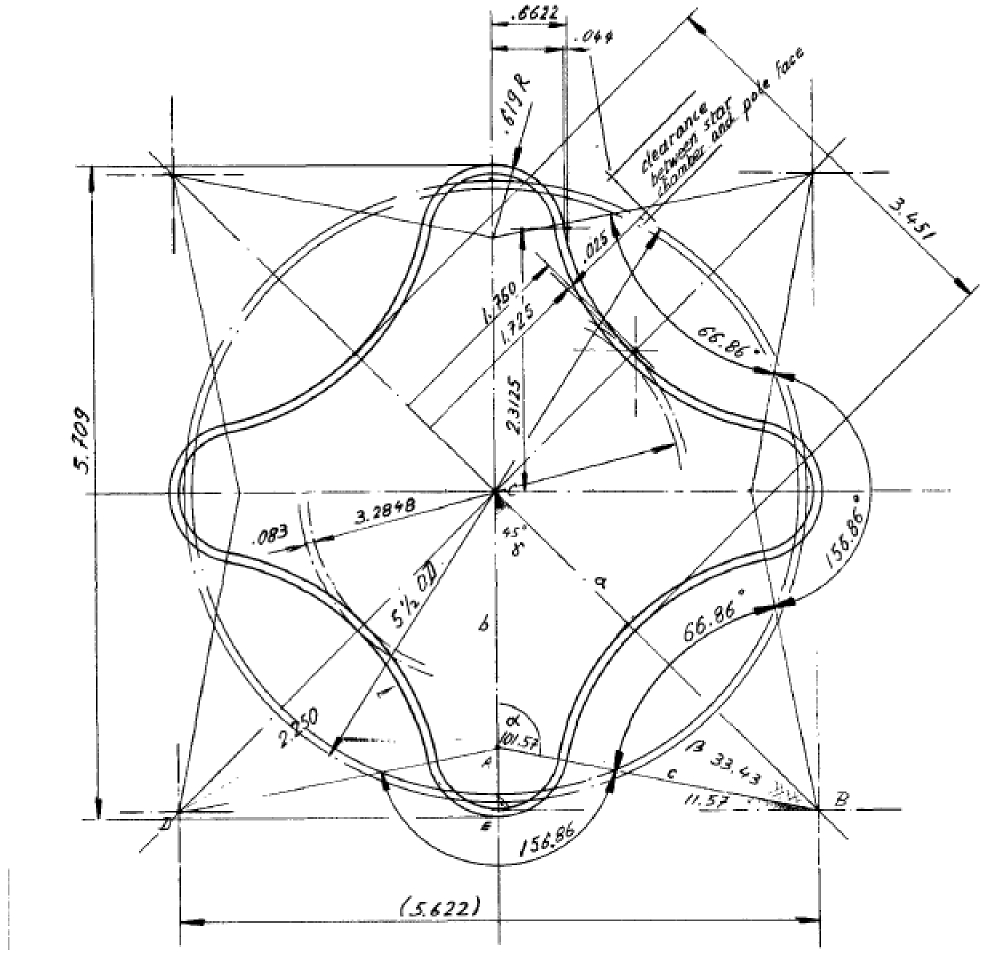


Figure 2: Large star vacuum chamber in SQ series quadrupoles. Appears in beamlines and delivery ring. Circular aperture diameter is 3.29" (83.55 mm) and length on axis is 5.62" (142.74 mm). Types are SQA, SQB, SQC, SQD, SQE with effective lengths 18.0"(457.2 mm), 25.2"(640.0 mm), 27.6"(701.04 mm),32.6' (828.04 mm)', and 51.6 (1310.64 mm)", respectively.

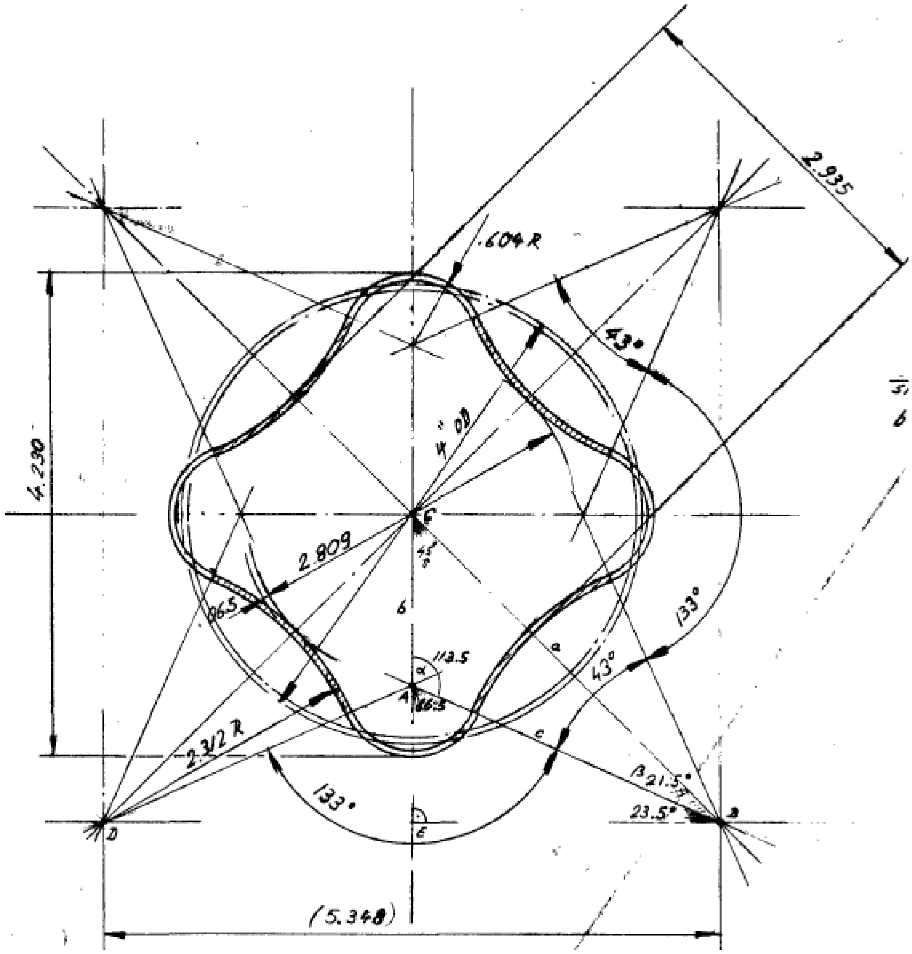


Figure 3: Small star vacuum chamber in SQ series quadrupoles. Circular aperture diameter is 2.81" (71.37 mm) and length on axis is 4.02" (102.10 mm). Types are SQA, SQB, SQC, SQD, SQE with effective lengths 18.0"(457.2 mm), 25.2"(640.0 mm), 27.6"(701.04 mm),32.6' (828.04 mm)', and 51.6 (1310.64 mm)", respectively.

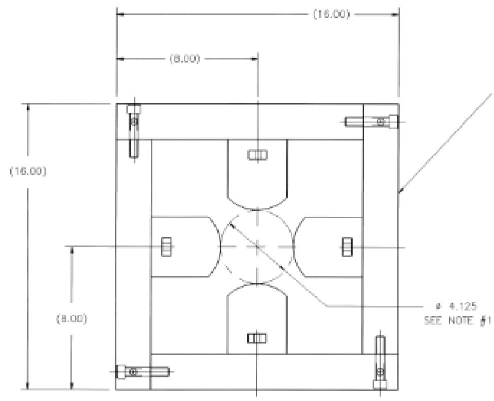
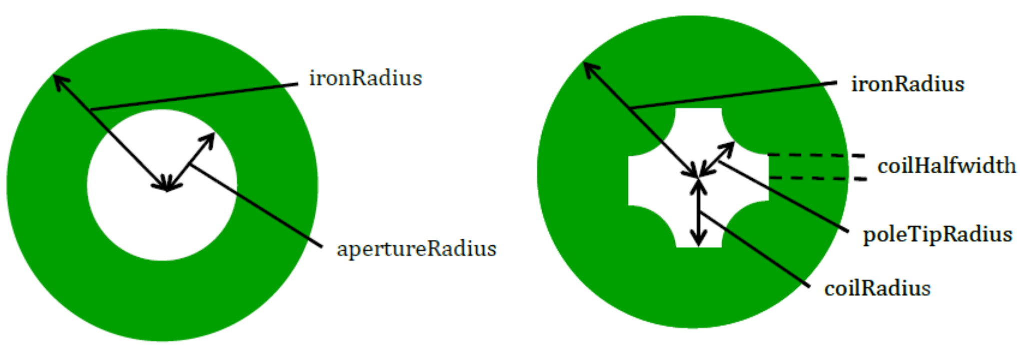


Figure 4: ANL/BNL 4" Quadrupole. The pole gap is 4.125" which corresponds to 104.775 mm. Two types 4Q16 and 4Q24 with lengths 16" (406.4 mm) and 24" (609.6 mm), respectively. 4Q24 is used at M2/M3 merge while two 4Q16 are used at M3 near DR injection.

2.2. Quadrupoles model in G4Beamline

The *genericquad* command can have two types of aperture: a circle and a “rounded +”. The former is specified by setting apertureRadius nonzero; the latter is controlled by the parameters shown in the figure. Note the rounded + aperture uses circles to approximate the poles (real magnet poles are between hyperbola and circle, to compensate for proximity to the neighboring pole and the coil).



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genericquad  construct a generic quadrupole magnet.

             The field region is a tubs with gradient specified. A positive
             gradient yields a horizontally-focusing quad for positive
             particles. If apertureRadius>0 the quad has a circular aperture.
             For a 'rounded +' aperture using circles for the poles, set
             poleTipRadius, coilRadius, coilHalfwidth. Due to visualization
             bugs, in the latter case you cannot see through the aperture; it
             is solid black. A fringe field computation based on the method of
             COSY INFINITY is included by default, extending the field region.
             This is first order only, and the fringe field extends outside of
             the magnet aperture only in a cylinder extending the aperture
             straight along local z. As the fringe field is first order only,
             it is slightly non-Maxwellian. It is computed using Enge
             functions.

             Note that there is no field inside the 'iron'; this can result in
             gross tracking errors for particles in the iron, and implies that
             kill=1 is desirable.

             If ironLength <= 0, no iron is constructed.

             Named Arguments (#=cannot be changed in place cmd):
             fieldLength    The length of the field region (mm)
             ironLength     The length of the iron (mm)
             ironRadius     The outer radius of the iron (mm)
             apertureRadius The radius of the aperture (mm)
             poleTipRadius  The inner radius of the pole tips (mm).
             coilRadius     The radius of the inside of the coil (mm).
             coilHalfwidth  The halfwidth of the coil (mm).
             coilHalfWidth  Synonym for coilHalfwidth.
             gradient       The magnetic field gradient, dBy/dx (Tesla/meter)
             maxStep        The maximum stepsize in the element (mm)
             ironMaterial   The material of the iron region.
             fieldMaterial  The material of the field region.
             ironColor      The color of the iron region.
             kill           Set nonzero to kill tracks hitting the iron.
             fringe         Fringe field computation, set to 0 to disable, or a
                            comma-separated list of 6 Enge function parameters.
             fringeFactor   Fringe depth factor (1.0).
             openAperture   Set nonzero to omit the aperture volume. #
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2.3. **Implementation of g-2 magnets in G4Beamline**

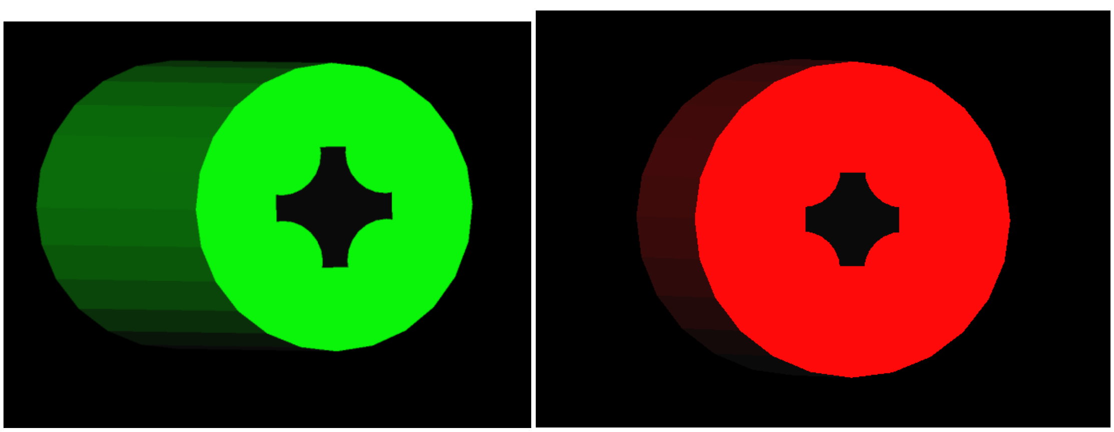


Figure 5: Left: Model for the large star vacuum chamber in SQ series quadrupoles. In the model we use poleTipRadius=41.7 mm, coilRadius=67.0 mm, coilHalfWidth=14.0, ironRadius=374.2 mm. Right: Model for the small star vacuum chamber in SQ series quadrupoles. In the model we use poleTipRadius=35.7 mm coilRadius=51.0 mm, coilHalfWidth=13.2, ironRadius=374.2 mm.

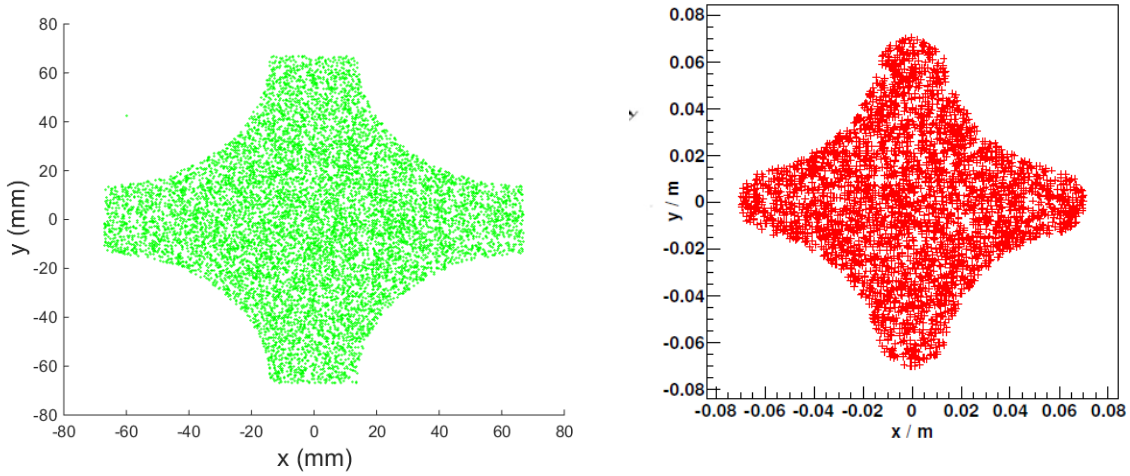


Figure 6: Left: G4Beamline model (Stratakis), Right: BMAD (G2-docB-2680) model. Note that the scales are different. The shown model is for the large star aperture quad.

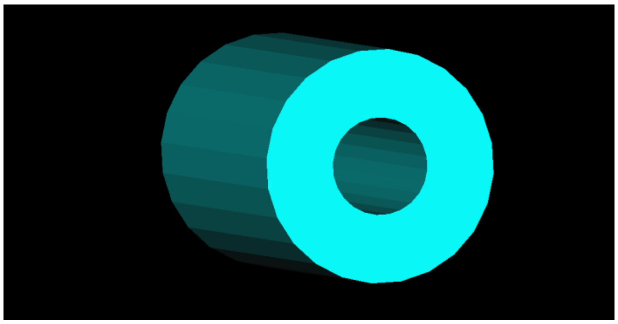


Figure 7: G4BL model for 4" quadrupole. In the model we assume apertureRadius=52.38 mm and ironRadius=172.1 mm.

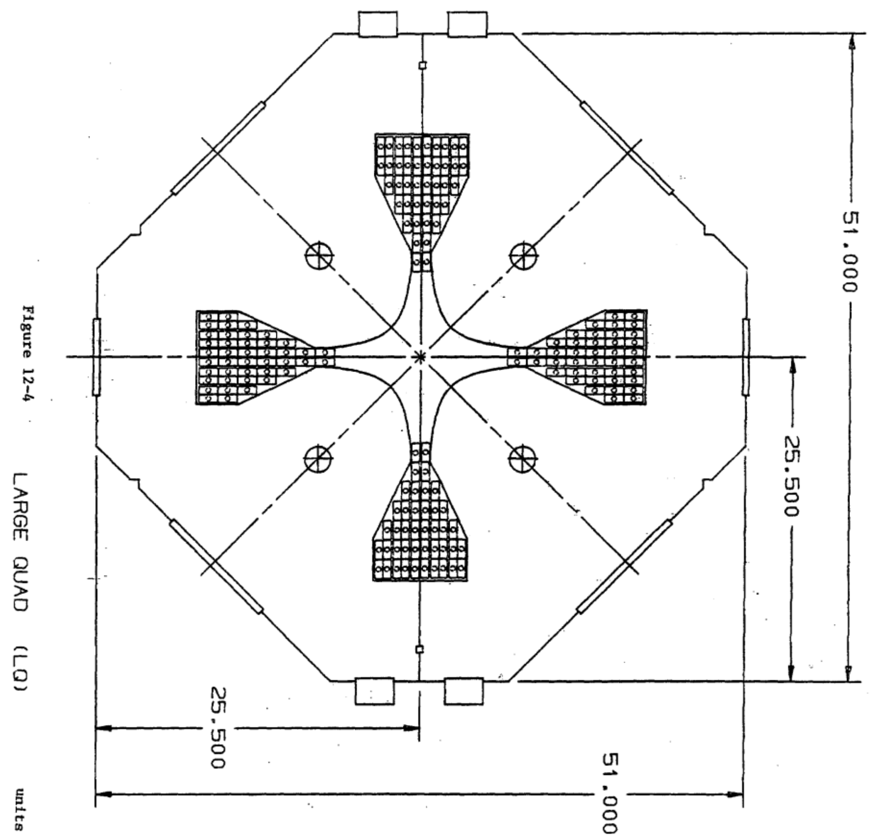
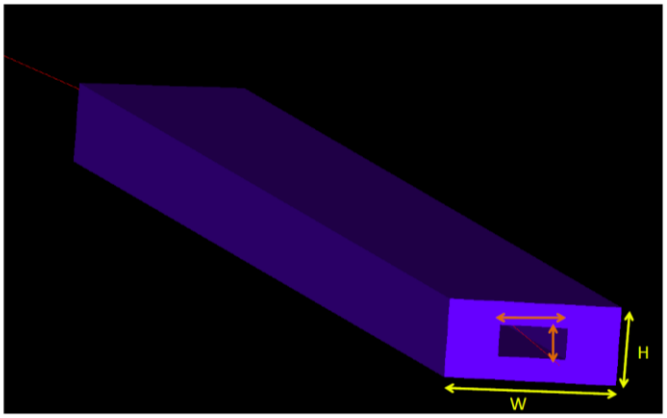


Figure 8: Actual design of the LQE magnet 303. In the G4BL model we use poleTipRadius=90.0 mm, coilRadius=180.0 mm, coilHalfWidth=30.0, ironRadius=660.0 mm. Adopted from Ref. 1.

Note: Quadrupole 302 magnet is modeled by assuming a SQ magnet but with three times larger aperture. In reality this is not optimum but good enough for a first pass study. Quadrupole magnet 301 is modeled as a conventional SQ magnet.

3. DIPOLES

From Jim Morgan:



My measurements are for a horizontal dipole, the wider aperture is in the bend plane. In cases where the dipoles are oriented vertically, reverse the dimensions.

5D32: Steel dimension - 5.125" horizontal, 4.125" vertical, vacuum pipe - 4.875" horizontal, 3.875" vertical
MDC: Steel dimension - 5.69" horizontal, 2.40" vertical, vacuum pipe - 5.44" horizontal, 2.25" vertical
SDB/SDD: Steel dimension (curved) - 7.0" horizontal, 2.375" vertical, vacuum pipe (curved) - 6" horizontal, 2.125" vertical
PMAG: Steel dimension - 2.0" horizontal, 1.37" vertical, no vacuum pipe (Target Station components are in air)

The "steel dimension" that I provided in the earlier email was referring to the inner dimension of the dipole steel, which is very close to the outer dimension of the vacuum chamber. Here are the full outer dimensions of the magnet steel, assuming a horizontal orientation:

5D32: 23.25" horizontal x 13" vertical
MDC: 25.25" horizontal x 14.25" vertical
SBD/SDD: 42.25" horizontal x 28" vertical
PMAG: 12" horizontal x 12" vertical

Below I convert Jim's numbers in mm.

PMAG:

Inner steel dimension is 50.8 mm horizontal and 34.80 mm in vertical plane.

5D32:

Horizontal: Steel 130.175 mm inner, 590.55 mm outer; vacuum is 123.825 mm

Vertical: Steel 104.775 mm inner, 330.2 mm outer, 98.425 mm vacuum

TBD

Figure 9: G4BL model for a 5D32 dipole

SDB/SDD

Horizontal: Steel 177.80 mm inner, 1073.15 outer, 152.40 mm vacuum

Vertical: Steel 60.325 mm inner, 711.2 mm outer, 53.975 mm vacuum

MDC

Horizontal: Steel 144.52 mm inner, 641.35 mm outer, 138.17 mm vacuum

Vertical: Steel 60.96 mm inner, 361.95 mm outer, 57.15 mm vacuum

LMDC:

Same but rotated 90 degrees to generate bending in vertical plane

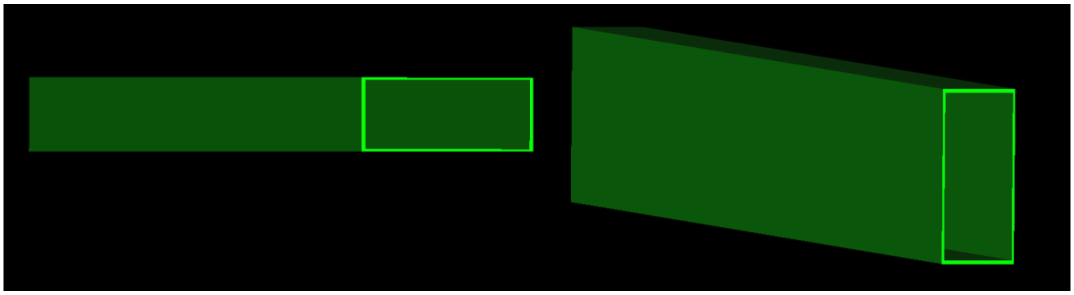
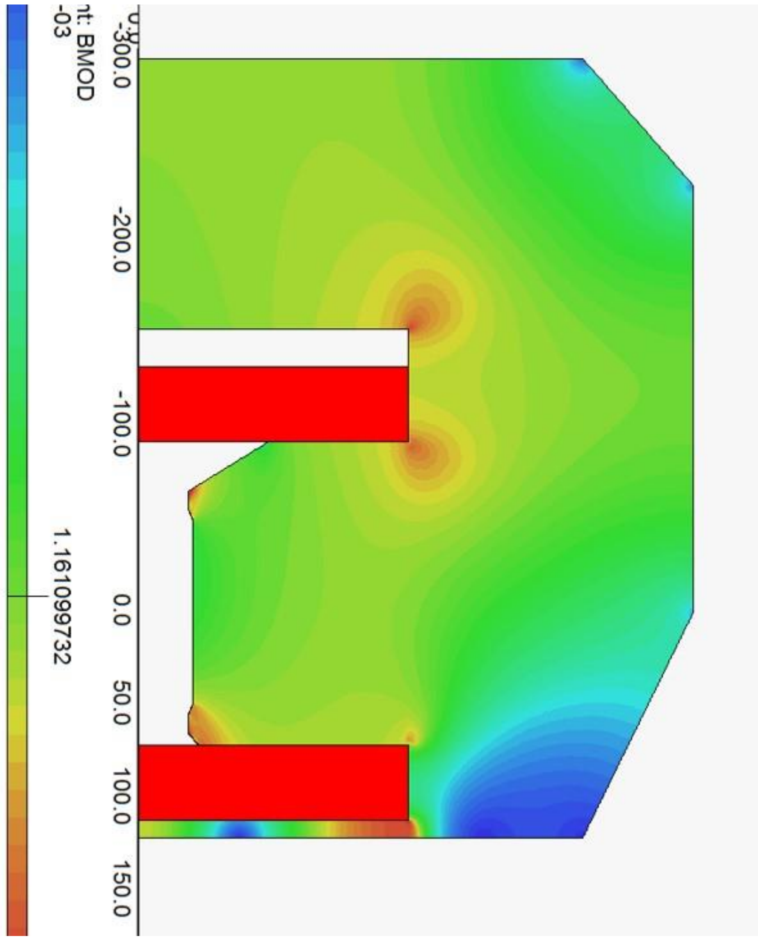


Figure 10: MDC dipole at two different orientations. Only vacuum and inner steel is shown

CMAG and Septum

The CMAG inner horizontal dimension is 51 mm and outer horizontal dimension is 600 mm, the inner vertical dimension is 200 mm and outer vertical dimension is 410 mm. Please note that the aperture isn't centered in the vertical aperture.



The Pulsed Septum has an inner horizontal dimension of 47mm and an outer horizontal dimension of 200 mm and a vertical inner dimension of 86 mm and an outer vertical dimension of 200mm. Again, this magnet is not symmetrical and it has curvature in the bend plane.

References:

[1] Design Report Tevatron 1 Project, FERMILAB-DESIGN-1984-01